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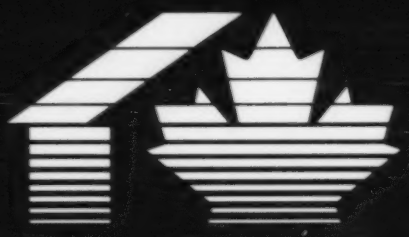

A Study of Energy Savings Using Low-Flow Showerheads

A RESEARCH REPORT

Energy, Mines and Resources Canada | Energie, Mines et Ressources Canada

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A Study of Energy Savings Using Low-Flow Showerheads

A RESEARCH REPORT

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The Buildings Energy Technology Transfer Program (BETT) of EMR has been created to assist building owners, users and practitioners active in the design, construction and operation of buildings in identifying technical obstacles to energy conservation. Through a nationwide network of research agencies and private sector consultants, BETT carries out research and development projects and provides the audiences mentioned above with technical reports, how-to manuals, training manuals, audio-visual aids and data bases to help them overcome these obstacles.

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ABSTRACT/RESUME

The report reviews the results of a research program carried out for the BETT Program to produce preliminary estimates of cost savings potential from use of low-flow showerheads in seven different building sectors, namely single family residence, family apartment, adult apartment, senior citizen apartment, hotel, recreational facility and school buildings.

A test methodology is described using battery operated individual shower monitors and an energy meter. Preliminary cost saving estimates and subjective user evaluation rankings are developed. Unfortunately, problems were experienced during the field testing section of the study which leave many questions unanswered and cast doubts about the user acceptability of low-flow showerheads.

* * *

Le rapport qui suit expose les résultats de recherches menées dans le cadre du Programme TTEB, en vue de faire une première estimation des économies que pourrait permettre l'emploi de pommes de douche à faible débit dans sept secteurs distincts du bâtiment, à savoir: maisons unifamiliales, habitations multifamiliales, immeubles d'appartements habités par des adultes seulement, immeubles d'appartements destinés aux personnes âgées, hôtels, installations de loisir et écoles.

L'essai s'est effectué à l'aide de moniteurs individuels alimentés par des piles et d'un compteur d'énergie. Les données relevées au moyen de ces appareils ont permis de faire une première estimation des économies probables. On a aussi coté les pommes de douche selon les préférences exprimées par les utilisateurs. Malheureusement, divers problèmes survenus pendant l'essai en situation réelle laissent beaucoup de questions sans réponse et mettent en doute l'acceptabilité des pommes de douche à faible débit pour le consommateur.

Le lecteur trouvera un sommaire du présent rapport, en français, à la page i.

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Le rapport qui suit résume les résultats d'un projet à plusieurs étapes, au cours duquel on a étudié les économies pouvant découler de l'emploi de pommes de douche à faible débit, ainsi que l'acceptabilité de tels appareils pour le consommateur. On y discute:

. la disponibilité de pommes de douche à faible débit;

. les résultats des évaluations de ces appareils en laboratoire;

. leur rendement en milieu réel;

. les préférences indiquées par les consommateurs participants; et

. la rentabilité des appareils.

Certains modèles sont d'un rendement acceptable, d'après les consommateurs ayant participé au projet. Les facteurs qui en favorisent l'acceptation par le consommateur sont notamment une pression plutôt élevée et un jet étendu aux gouttelettes de taille moyenne. Les modèles dont le rendement ne respectait pas ces critères ont été cotés médiocres par les participants, qui ont jugé la moitié des appareils expérimentés de modérément à légèrement insatisfaisants.

Des actes de vandalisme perpétrés au centre culturiste de Toronto of l'on expérimentait certains des modèles de pommes de douche ont beaucoup limité l'utilité des données relevées en milieu réel. Néanmoins, les pommes de douche à faible débit semblent rentables. Comme on peut le constater à la lecture du tableau qui suit, elles permettent d'épargner jusqu'à 35 $ par année dans les maisons unifamiliales et un peu moins dans les autres genres d'immeubles. Il faut remarquer cependant que certaines des prévisions données - dans le cas des établissements de culturisme, par exemple - ont été calculées en fonction d'un utilisateur unique et que les économies globales correspondraient donc au produit des montants cités par le nombre d'utilisateurs de chaque douche.

POTENTIEL ECONOMIQUE DES POMMES DE DOUCHE A FAIBLE DEBIT: ESTIMATION PRELIMINAIRE DES ECONOMIES COMPOSEES

Genre d'immeuble	Economie annuelle d'énergie d'eau chauffée		Economie annuelle d'eau	Economie composée
	Au gaz	A l'électricité		
Maison unifamiliale	18,40 $	28,50 $	7,05 $	25,45 $ à 35,55 $
Habitation multifamiliale (par app.)	10,00 $	11,00 $	6,15 $	16,15 $ à 17,15 $
Immeuble d'appartements habités par des adultes seulement (par app.)	6,10 $	6,70 $	3,75 $	9,85 $ à 10,45 $
Immeuble d'appartements destinés à des personnes âgées (par app.)	3,00 $	3,30 $	1,85 $	4,85 $ à 5,15 $
Hôtel (par chambre)	3,90 $	4,30 $	2,40 $	6,30 $ à 6,70 $
Installation de loisir (par membre)	2,50 $	2,80 $	1,55 $	4,05 $ à 4,35 $
Ecole (dortoir) (par étudiant)	4,90 $	5,40 $	3,05 $	7,95 $ à 8,45 $

NOTA:

(1) Les estimations ci-dessus supposent une baisse de 33% du débit d'eau, lorsqu'on emploie une pomme à faible débit; la consommation d'énergie diminue toutefois de 30% seulement, en raison de la durée prolongée des douches et de la quantité proportionnellement plus élevée d'eau chaude utilisée.

(2) Les économies pécuniaires résultant de la baisse de la consommation d'eau ont été calculées d'après la taxe d'aqueduc facturée par la Ville de Toronto en octobre 1985 et tiennent compte de frais supplémentaires de 15% pour le tout-à-l'égoût.

This report outlines the findings of a staged project to investigate the cost savings potential and user acceptability of low-flow showerheads. The report is divided into sections outlining low-flow showerhead:

- availability;
- laboratory evaluation;
- field performance;
- subjective evaluation;
- economics.

The study demonstrates that some low-flow showerheads perform in an acceptable fashion, according to a subjective evaluation panel. Factors which tended to promote user acceptability included wide spray dispersion, medium spray size and moderate to high water pressure. Showerheads which did not perform in accordance with these criteria were down rated by the user panel. Half of the tested showerheads were disliked moderately to slightly, according to the panel.

Problems with vandalism were encountered when the showerheads were installed in a Toronto health club, severely limiting the usefulness of the field data.

The economics of low-flow showerheads appear attractive. Cost savings of up to $35 per year are possible for single family residences, with lesser savings potential for other building types. It should be noted, however, that for applications such as health facilities, the predicted savings are on a per user basis, savings would be multiplied by the number of users per shower.

Use of low-flow showerheads has been suggested by many as a low cost method of energy conservation. There is little information available however which scientifically documents water use patterns for various types of buildings, making it difficult to predict the water and energy savings potential of low-flow showerheads.

In an attempt to fill this void, ORF under the auspices of the Buildings Energy Technology Transfer Program prepared a staged workplan consisting of laboratory and field evaluations of low-flow showerheads, combined with a review of available literature on the subject and a subjective evaluation to develop the necessary data.

This report details the methods used and the results obtained during the study.

1.1 Background

Use of low-flow showerheads is frequently suggested as a means for reducing consumption of domestic hot water and associated energy. Under controlled laboratory conditions, these low-flow showerheads do, indeed, perform as expected. Other factors, such as increased showering time and/or increased mixed water temperature necessary to offset any cooling effects brought about by induction of air into the water stream, may reduce or eliminate any energy-use benefits which are predicted solely on the basis of laboratory test data. This project was undertaken in an attempt to eliminate these uncertainties and to obtain meaningful data on the energy use reduction of low-flow showerheads.

1.2 Objectives

The objectives of the project can be summarized as follows:

- to identify and quantify actual energy use reduction resulting from low-flow showerheads;
- to establish economics of low-flow showerheads;
- to develop suitable monitoring packages to allow field measurement of water and energy;
- to provide documented information about the performance of low-flow showerheads for eventual development into technology transfer documents (fact sheets, etc.).

In order to assess the performance of low-flow showerheads, a laboratory test facility was designed and constructed at ORF for measurement of water flow rates and flow characteristics of showerhead and faucet aerators. The design and construction of this facility is detailed in earlier reports. The actual test procedure, however, is repeated below.

2.1 Test Procedures for Showerheads and Showerhead Adaptors

(1) Install the showerhead in the test stall, cleaning it first if necessary. A showerhead adaptor is to be installed in conjunction with a standard showerhead.

(2) Set to full flow rate and examine for leaks.

(3) Measure the volumetric flow rate at 50, 100, 200, 300, 400 and 500 kPa. At least four readings of the flow rate shall be made and recorded at each pressure. The pressure shall not vary by more than 10 kPa from the set point during the time in which the flow rate is being measured.

(4) Set the height of the plastic sheet to 0.815 m and adjust the pressure until the highest stream just touches the sheet. Record the volumetric flow rate (4 readings) and the pressure. This will give the flow rate at a nozzle velocity of 4.0 m/s.

(5) Adjust the height of the plastic grid to 0.46 m above the showerhead. Adjust the pressure such that the highest stream just touches the grid. Record the pressure as the pressure necessary to obtain a nozzle velocity of 3.0 m/s.

(6) With the plastic grid still at 0.46 m adjust the pressure to that determined in 4 for a "comfortable" shower. Record the pattern of the spray on the grid on a sheet of graph paper. Ensure that the number of points recorded corresponds to the number of holes in the

showerhead. If the spray is such that a distinct pattern cannot be recorded, measure the approximate diameter of the pattern on the grid. Note any offshoots of water.

(7) Attach the copper plate with temperature probe to the underside of the plastic grid and adjust the height such that the plate is 0.46 m above the showerhead. With the driving pressure as determined in step 4 adjust the water temperature plate to 40°C. Allow sufficient time for the temperature of the plate to stabilize. Record the temperature differential between the plate and the water upstream of the showerhead. The rated temperature is 40°C plus the temperature drop of the water from the showerhead to the plate.

2.2 Selection of Low-Flow Showerheads for Testing

2.2.1 Product Survey

A form letter was prepared for distribution to manufacturers and distributors of plumbing products appropriate to the domestic hot water market. A mailing list of these companies was compiled from the 1982 Fraser's Canadian Trade Directory, the 1981 Thomas Register of American Manufacturers and internal sources. The letter was then distributed to fifty-five Canadian and nine American manufacturers and distributors during November, 1982. Eighteen positive (and four negative) replies were received.

The majority of devices on the market were found to be flow-restricting aerators and low-flow showerheads, either designed for retrofit or new equipment applications (ten responses). In certain cases, pressure limiting valves and thermostatic limiting valves can also reduce domestic hot water consumption (two responses).

Data on institutional wash fountains for both retrofit and new applications, and institutional metering faucets for new applications were received.

While these devices do appear to have a potential for reducing hot water use they were deemed to fall outside of the scope of this program. A summary of the data obtained is attached in Appendix A, as well as a copy of the letter sent to manufacturers.

2.2.2 Manufacturers' Claims Regarding Low-Flow Showerheads

The results of the survey questionnaire were compiled and are summarized in Table 2.1. It should be noted that these figures were based on manufacturers' or distributors' claims which were generally not well documented. No indications were given of the source of the quoted flow rates for "conventional" showerheads.

TABLE 2.1: SUMMARY OF MANUFACTURERS' CLAIMS FOR LOW-FLOW DEVICES

Item	Low-Flow Avg. and Standard Deviation (L/min)	Conventional Avg. and Standard Deviation (L/min)	% of Water which is hot	Shower Time (Minutes)
Showerheads	9.9 $\pm$ 2.1	26.6 $\pm$ 6.1	30 to 50%	5, 7, 10
Faucets	8.1 $\pm$ 1.5	19.7 $\pm$ 7.0	-	Not Applicable

For showering, the quoted range of hot water usage varies from 30% to 50% of total flow according to the survey results. This is slightly below other data which suggests that for "typical" Canadian conditions approximately 60% of hot water at 60^{o}C must be blended with approximately 40% of city water at 8^{o}C to obtain a comfortable mixed end-use temperature of 40^{o}C [1].

Based on the responses to the survey questionnaire, and discussions with plumbing distributors, a total of thirty one showerheads were identified for laboratory testing. Twenty nine of these showerheads were classified as low-flow units according to the survey responses. Three samples

of each unit were ordered to assess sample-to-sample variations in measured water consumption. One additional showerhead was tested in the laboratory during a later phase of work (field evaluation).

2.2.3 Laboratory Test Results

The findings of the laboratory tests are categorized by the following criteria:

- flowrate characteristics;
- temperature drop characteristics;
- spray characteristics.

The results of the tests are summarized in Table 2.2. A discussion of the results in the context of the three criteria identified above follows.

Flowrate Characteristics

The flowrates of the low-flow showerheads tested at a pressure of 300 Pascal (45 psig) ranged from 4.4 to 13.3 litres per minute (1 to 2.9 IGPM), with an average of 8.5 litres per minute. The showerheads in Table 2.2 are listed in order of increasing flowrate at 300 kiloPascal pressure.

A study undertaken in the U.S. [2] indicated the average flowrate for non-conserving showerheads to be 15.3 litres per minute. This is in agreement with an estimate from a CEA report [3] of 15.9 litres per minute. The flowrates for two conventional showerheads tested in this task were 16.3 litres per minute at 150 kPa and 20.4 litres per minute at 100 kPa. The average flowrate for low-flow showerheads in the U.S. study was 8.6 litres per minute as compared to an average of 8.5 litres per minute at 300 kPa for the showerheads tested in this part of the study.

TABLE 2.2 SUMMARY OF TEST RESULTS

SHOWERHEAD MFG. & MODEL	PRICE $ CAN.	MEAS. FLOW L/min @300 kPa	COMPOSITION	DIA.OF SPRAY @ .40m (cm)	COARSE-NESS[1]	EVENESS[2]
CRADO S 1002	18.35	4.35	Chrome Plated Brass	20 - 25	0	2
WALTEC A6594	13.91	4.57	Chrome Plated Plastic, Plastic	23 - 25	A,1	2
M.F.ADAMSON & ASS. 322 Turbojector	26.00	5.85	Aluminum, Chrome Plated Brass	18 - 20	0	2
CON-SERV INC. Nova B6402	26.00	6.6	Chrome Plated Brass	23 - 25	0	2
M.F.ADAMSON & ASS. 323 Turbojector	26.00	6.96	Aluminum, Plastic	15 - 20	0	2
TRANSCONTINENTAL ENERGY SAVING PRODUCTS, CANADA (STANDARD)	15.95	7.05	Chrome Plated Brass	25 - 30	0	2
JENKINSON & CO. 6005C	11.30	7.09	Chrome Plated Brass	23 - 28	0	2
CHICAGO SPECIALTY 123WS	4.70	7.48	Plastic	20 - 25	2	2
JENKINSON & CO. 14-9513	9.00	7.51	Plastic, Chrome Plated Plastic	25 - 30	1	2
JENKINSON & CO. 6001C	13.20	7.58	Chrome Plated Brass	20 - 25	0	2
TRANSCONTINENTAL ENERGY SAVING PRODUCTS, CANADA (DECORATOR)	28.90	7.6	Chrome Plated Brass	15 - 18	0	2
JENKINSON & CO. 14-9800	13.50	7.75	Chrome Plated Plastic, Plastic	20 - 25	2	2
TRANSCONTINENTAL ENERGY SAVING PRODUCTS, CANADA (BUDGET MASTER)	10.90	7.97	Chrome Plated Brass	23 - 29	1	2
MOEN 2166A	49.14	8.05	Chrome Plated Brass, Plastic	28 - 33	1	2
JENKINSON & CO. 6007X	11.30	8.71	Chrome Plated Brass	23 - 25	0	2
MOEN 3936	41.80	8.83	Chrome Plated Brass, Plastic	28 - 33	A,1	2
DANCO S1014	8.30	8.84	Chrome Plated Plastic, Plastic	10 - 25 (adjustable)	2	0
MOEN 3900A	8.08	8.89	Chrome Plated Plastic, Plastic	15 - 18	2	2
JENKINSON & CO. 3111R	3.70	8.92	Plastic, Chrome Plated, Plastic	20	A,2	2
ONDINE C28444	6.50	9.11	Plastic, Chrome Plated, Plastic	23 - 36	A,0	2
JENKINSON & CO. Insert 3100	2.75	9.18	Chrome Plated Brass	18 - 28		
WALTEC 20D335	12.70	9.44	Chrome Plated Brass, Plastic	33	1	2
MOEN 3905	34.73	10.25	Chrome Plated Brass, Plastic	23 - 28	A,1	2
WATER-PIK S7-22[3]	47.74	10.4	Plastic, Chrome Plated, Plastic	29	1	2
MOEN 1533	12.77	10.93	Chrome Plated Brass, Plastic	23 - 33	2	2
DANFOSS WATER SAVER	24.79	11.34	Plastic, Chrome Plated, Plastic	10 - 25	A,2	1
CHATHAM 4435	42.00	11.7	Chrome Plated Brass	18 - 30	A	
CRADO S1010	10.00	13.12	Chrome Plated Plastic	18 - 30	A,2	1
EMCO	9.92	13.3	Plastic	22	2	2
CHICAGO SPECIALTY 127C	13.60	18.6[4,5]	Plastic, Chrome Plated, Plastic	30 - 38	A,2	2
JENKINSON & CO. 3130	6.50	19.8 -21.4[4,6]	Chrome Plated Plastic, Plastic	25 - 28	2	2

[1] Coarseness (spray size) 0 - fine, 1 - medium, 2 - coarse, A - adjustable
[2] Eveness 0 - poor, 1 - adequate, 2 - good
[3] Spray pulse adjustable, pulse mod.
[4] Standard shower head
[5] Flow measured at 200 kPa
[6] Measured flow at 100 kPa

Temperature Drop Characteristics

The temperature drop measured was about 1°C for the non-conserving showerhead, and ranged from 1°C to 5°C for the low-flow showerheads. In general, the lowest flow showerheads exhibited the highest temperature drop. With this greater temperature drop, the user may increase the water temperature entering the showerhead to achieve the same comfort level.

Spray Characteristics

The diameter and coarseness of the shower spray were noted at the time of testing. This information is summarized in Table 2.2.

It was evident from the laboratory test phase of the program that low-flow showerheads did indeed save water and energy in a laboratory environment. There was no guarantee, however, that in a real world situation the users would not simply increase the shower time or open the shower taps more, thereby raising the water pressure at the showerhead and consequently the flow. Acceptability of the shower spray pattern was also open to question, and the temperature reductions measured during laboratory tests lend credence to the suggestions of increased mixed water temperatures when low-flow showerheads are in use.

In an attempt to resolve these concerns, it was decided to carry out a field monitoring program at an athletic facility to develop the necessary information.

3.1 Test Methods and Equipment

An instrumentation package was designed by ORF to enable monitoring of the following parameters:

- Hot water consumption
- Cold water consumption
- Energy use (defined as the energy content in the hot water and obtained by integrating the mass flow-rate of hot water and enthalpy increase between the cold and hot water)
- Showering time
- Total number of showers taken

The instrumentation package consisted of individual showerhead monitors activated by a switch sensitive to water pressure. These battery powered units were designed to trigger an event counter and operate an elapsed time totalizer whenever the pressure switch sensed that the shower was in operation.

In addition to the battery powered individual showerhead monitors, a cold water totalizer and a hot water totalizer were used to measure the amount of water used by the block of showers. The hot water totalizer was modified to generate a pulse signal which was input to an energy meter as well

as the output from hot and cold water temperature sensors. This meter provides for direct measurement of energy consumption. A schematic of the monitoring package is shown in Figure 3.1.

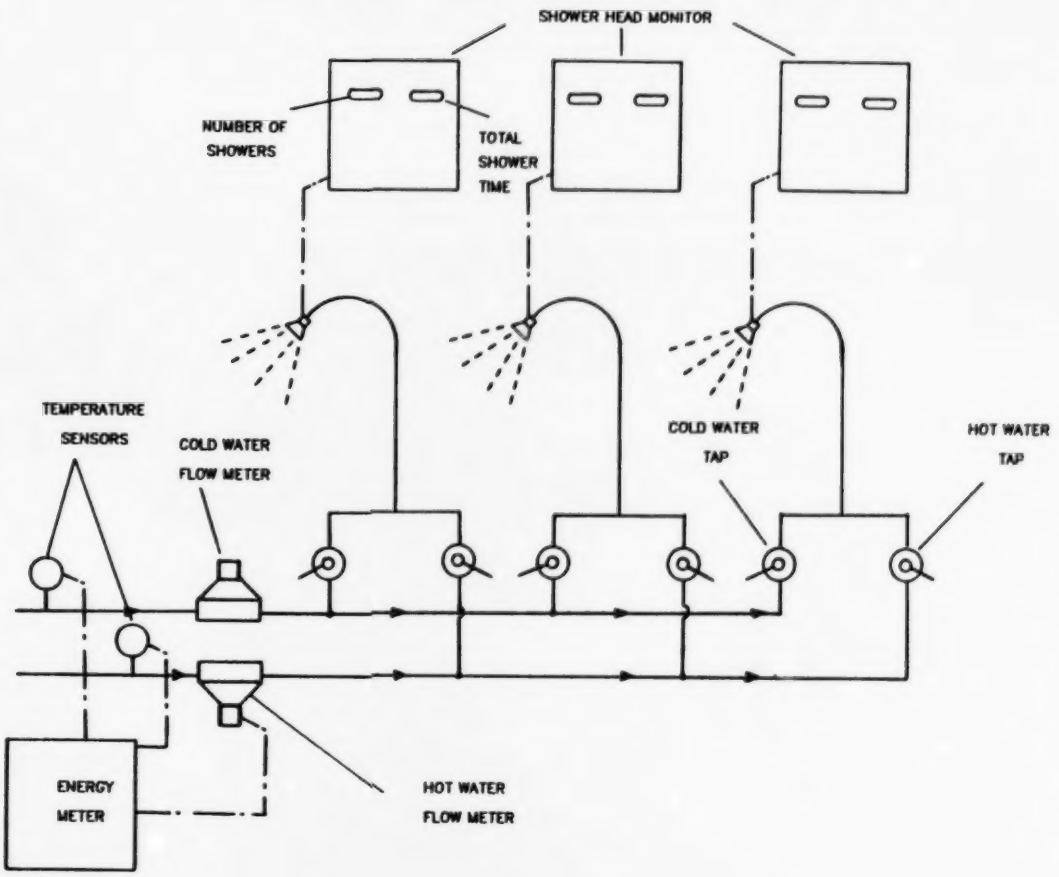

Figure 3.1 Shower Energy Use Monitoring Schematic

3.2 Selection of Test Site

Selection of a site to install the monitoring package proved to be rather difficult. It was desirable to determine energy savings in a location

where a large number of showers could be monitored over a fairly short time period, but at the same time, it was essential that the plumbing system at the test site was of a type which would be typically found in the other building categories. This required a "two-tap" plumbing installation where the end user has control of both the cold and hot water shower faucets.

A number of fitness centres were contacted to solicit their cooperation in the monitoring program. It soon became evident, however, that the majority of health clubs and fitness centres in the Toronto area use a one-tap plumbing system in their shower facilities. The Columbus Centre is a noteworthy exception to this generality.

Columbus Centre, located at Dufferin Street and Lawrence Avenue in Toronto has a facility known as the men's health club. This facility has eight showers which could be isolated from the remainder of the plumbing system of the building for monitoring purposes. The plumbing system used in the showers is a standard "two-tap" design. Hot water is pumped from a storage tank to a mixing valve where it is blended with city water to a temperature of nominally 45°C and supplied to a hot water supply loop for the showers. Cold water supplied to the shower taps is untempered city water.

The Columbus Centre agreed to allow ORF access to the facilities for monitoring subject to certain conditions (refer to letter from Columbus Centre - Appendix A).

Ten models of showerhead were selected for testing at the centre. Nine of these were taken more or less randomly from the sampling tested in the laboratory. One other model was included, the Chatham 44-3S, which was already installed at Columbus Centre. This showerhead was subsequently tested under the same laboratory conditions and was found to have a flowrate of 11.7 L/min under the 300 kPa water pressure test condition. Tested showerheads are shown in Table 3.1.

Table 3.1 Tested Showerheads and Measured Flow Rates

Showerhead Mfg. & Model	ORF Measured Flow @300 kPa (L/min)
Crado Model S 1002	4.4
Waltec Model A 6594	4.6
Con-serv Inc. Nova B 6402	6.6
M F Adamson, Model 323 Turbojector	7.0
Transcontinental Energy Saving Products, Canada Standard Model	7.1
Chicago Specialty Model 123 WS	7.5
Jenkinson & Co. Model 6001 C	7.6
Moen Model 3936	8.8
Chatham 44-3S (low-flow unit originally installed at Columbus Centre)	11.7
Chicago Specialty Model 127 C (conventional showerhead)	18.6 (@200 kPa)

3.3 Test Results

The test results are shown in Table 3.2. The test results from the facility were extremely disappointing. Problems were initially experienced with the battery powered showerhead monitor units. The timer units were not operating correctly and were indicating average shower times in the order of 1 to 2 minutes. The problem was traced to a component used in the totalizing timer. The particular timer used had a specified resolution to

Table 3.2 COLUMBUS CENTRE TEST DATA

Showerhead Designation	No. Showers	Energy Used (kWh)	Hot Water (m^3)	Cold Water (m^3)	Monitoring Period (1985)	Hot and Cold Water Used per Shower (L)	Energy per Shower (kWh)
Chatham 44-3S	1826	1659	46.00	5.23	3/1-7/1	28.1	0.909
Moen 3936	3445	2682	65.75	1.09	7/1-14/1	19.4	0.779
Turbojector 323	3311	2363	49.20	3.65	14/1-21/1	16.0	0.714
Chicago 127C	749	922	18.12	0.57	14/2-15/2	25.0	1.231
Chatham 44-3S	2225	2166	44.40	1.22	15/2-18/2	20.5	0.973

1/100th hour or 36 seconds, but was a digital device using the charge/discharge time of a capacitor as a time-base generator. If the capacitor were initially totally discharged when the showerhead pressure switch was closed (i.e. shower use was detected) the capacitor would not charge sufficiently to activate the time-base for a period of 50 to 60 seconds. If, on the other hand, the capacitor were already charged when the shower switch was closed, there would be no time lag in the response of the timer. In both cases, however, the timer counter would not be advanced until 1/100th of an hour after the time-base generator were activated. It was therefore possible that a shower of short duration (up to 90 seconds) would not be registered by the timer unit, although the event would be recorded by the counter unit.

In view of the data which was being obtained from the Centre showing average recorded shower times in the range of one to two minutes the errors in the timers were unacceptable. A modification was therefore undertaken which involved substituting the time-base capacitor and certain other changes.

These modifications improved the resolution of the timers by a factor of 100, and reduced measurement uncertainties to the order of one second per shower event. This modification was not, however, undertaken until late in the monitoring program. It should be noted that data obtained for energy and water use is not affected by this problem.

Without any notification to ORF, Columbus Centre arranged to have the heating boilers cleaned at the end of January. Some users subsequently reported an increase in water pressure. This may also have some impact on readings.

A more fundamental problem experienced at the test site concerned the reaction of the health club members to the monitoring program itself. It should be mentioned that the men's health club members are a group who pay nearly $400 per year in fees and have certain privileges over and above those of ordinary members. There appeared to be a negative attitude towards the program and a feeling

from certain health club members that the monitoring program which was underway would, in some way, result in additional costs or inconvenience to the members. We attempted to alleviate these concerns by posting a notice in the change areas outlining the scope and planned duration of the project and leaving some "subjective evaluation questionnaires" with an attendant for distribution to interested members.

It quickly became evident, however, that there was no improvement in the members' perception of the worth of the study (refer to Sampling of Questionnaires - Appendix A). The problems came to a head one day when the monitoring equipment was vandalized by unknown members as an apparent protest against the project or other perceived injustices.

The equipment was repaired and re-installed and it was decided to attempt to avoid any further problems of this type by accelerating the showerhead change-out schedule and again posting signs informing the members that any perceived inconvenience associated with the monitoring equipment and/or test showerheads would be for a short duration only. Nevertheless, the equipment was again vandalized during a period in which the attendant was not present.

It is interesting to note that the showerhead which was installed immediately before the second occurrence of vandalism was the Chatham 44-3S, which was the unit originally installed at the health club. Subsequently, this showerhead was favourably reviewed by the Consumer's Association of Canada (see the Subjective Evaluation Section of this report) and was top rated by the U.S. magazine, Consumer Reports, in their June 1985 review of low-flow showerheads. This may have tended to exaggerate the shortcomings of the other low-flow showerheads which were used.

A subcontract was awarded to the Consumers Association of Canada (CAC) to carry out a subjective evaluation of low-flow showerheads. The objectives of this phase of the program were to identify which characteristics of showerheads are important to the user and to develop a method to quantify the acceptability of the test showerheads. The same ten models of showerheads were evaluated by the CAC as were tested at the Columbus Centre.

4.1 Test Methods and Equipment

A questionnaire was developed to give an overall preference rating for each showerhead. Users were also asked to evaluate specific characteristics and to indicate why they either liked or disliked any particular sample.

Nineteen users took samples of each showerhead home and used each for a period of 3 to 4 days. At the end of that period they reported on its performance using the questionnaire provided. It was then replaced with another showerhead. It took six weeks to complete testing in this manner.

CAC's method of operation was to fit the first showerhead to the user's regular shower before leaving and follow up by telephone on day four to ensure that the second showerhead had been fitted satisfactorily. The following week the tested showerheads were picked up and a new set of samples provided. During this time the users' results were discussed.

This was to ascertain if any unforeseen circumstances had affected their results. The questionnaires were checked to make sure there were no omissions and to get explanations as to why there may have been trouble answering certain questions.

After the questionnaires were completed and showerheads returned, results were compiled and analyzed.

The user panel consisted of 9 females, (three 20-30 year olds, five 30-40 year olds, and one 50-60 year old). Ten were males, (three 20-30 year olds, five 30-40 year olds, one 40-50 year old and one 50-60 year old).

Each showerhead was evaluated by the user panel for performance in the following key areas:

- Water pressure: was rated for acceptance. It identified the magnitude of force produced by each showerhead.
- Spray dispersion/patterns: rated for acceptance, it identified each showerhead's spray width, spray size, spray pattern and pattern adjustability.
- Noise level: identified which were significantly noisier than others.
- Time in the shower: identified which showerheads took the longest to use, thereby negating any potential energy savings. It also showed which took the shortest amount of time to use, thus adding to their energy conservation potential.
- Hot and cold water usage: determined whether or not there was a perceived difference among showerheads in relation to the amount of hot water used. If more hot water than normal was necessary to operate a showerhead, its energy savings potential could be negated.
- Overall preference/acceptability: this is the main guideline to each showerhead's performance. Users took into account every question asked on the questionnaire plus things not outlined, but significant to their acceptance of the product. An example of an un-asked but influencing concern was the cooling effect of the fine perimeter spray as well as the inability of some showerhead neck joints to swivel far enough.

Different techniques were used to analyze both the preference/acceptance testing and difference testing of samples.

Mean scores, modal scores and analysis of variance were used in the statistical analysis of user responses.

Spray and water pressure acceptance were based on a five point system in which 5 was excellent, 4 was good, 3 was satisfactory, 2 was fair and 1 point was poor.

Overall showerhead preference was based on a nine point scale which was then condensed to a five point scale. Five points was "like extremely to very much", 4 points was "like moderately to slightly", 3 points was "neither like nor dislike", 2 points was "dislike slightly to moderately" and 1 point was "dislike very much to extremely".

4.2 Test Results

The results of the test are summarized in Tables 4.1 to 4.3. The tested showerheads could be divided into 3 groups: those "disliked slightly to moderately", those "neither liked nor disliked", and those "liked slightly to moderately". When the showerheads were categorized into the 3 groups, their specific characteristics were tabulated (see Table 4.4), and certain trends appeared.

The lowest rated showerheads, "disliked slightly to moderately", had fine spray size, narrow to medium spray width and produced moderate to light water pressure. The spray pattern and water pressure for the lowest category was rated fair.

The one showerhead in the middle group, "neither liked nor disliked", was perceived to have a medium spray size, narrow to medium spray width and produced moderate water pressure.

TABLE 4.1 SHOWERHEADS GROUPED BY OVERALL PREFERENCE RATING

NO.	BRAND/MODEL	SPRAY ADJUSTABILITY	FLOW RATE (L/min)	OVERALL PERFERENCE RATING	ACCEPTANCE RATING	WATER PRESSURE CHARACTERISTICS
1	Crado S1002	Not adjustable	4.4	2	2	
2	Waltec 76594	Adjustable	4.6	2	2	light to moderate
3	Con-serv Nova 86402	Adjustable	6.6	2	3	moderate
4	Adamson 323 Turbojector	Adjustable	7.0	2	3	moderate to heavy
5	Transcontinental Standard	Not adjustable	7.1	3	3	moderate
6	Chicago Sp. 123WS	Not adjustable	7.5	2	2	light to moderate
7	Jenkinson 6001C	Not adjustable	7.6	4	4	moderate to high
8	Moen 3936	Adjustable	8.8	4	3	moderate to high
9	Chicago Sp. 127C	Adjustable	18.6	4	4	moderate
10	Chatham 44-3S	Adjustable	11.7	4	4	moderate

5 - Excellent
4 - Good
3 - Satisfactory
2 - Fair
1 - Poor

TABLE 4.2 SHOWERHEADS GROUPED BY OVERALL PREFERENCE RATING

NO.	BRAND/MODEL	SPRAY ACCEPTANCE RATING	SPRAY WIDTH	SPRAY SIZE	SPRAY PATTERN	RATED SPRAY ADJUSTABILITY RANGE
1	Crado S1002	2	narrow to medium	fine	no centre, uneven	not adjustable
2	Waltec 76594	2	medium to wide	fine to medium	no centre	poor range
3	Con-serv Nova 86402	2	medium to narrow	fine	no centre, uneven	not adjustable
4	Adamson 323 Turbojector	2	narrow	-	uneven	poor range, not adjustable
5	Transcontinental Standard	3	medium to narrow	medium	no centre, heavy centre	not adjustable
6	Chicago Sp. 123WS	2	narrow to medium	medium to fine	no centre, uneven	not adjustable
7	Jenkinson 6001C	3	narrow	fine to medium	no centre	not adjustable
8	Moen 3936	3	wide	medium to fine	no centre	poor range
9	Chicago Sp. 127C	3	medium to wide	medium	no centre	poor range
10	Chatham 44-3S	4	wide	medium to coarse	heavy centre no centre even	poor range good range

5 - Excellent
4 - Good
3 - Satisfactory
2 - Fair
1 - Poor

TABLE 4.3 SHOWERHEADS GROUPED BY OVERALL PREFERENCE RATING

NO.	BRAND/MODEL	NOISE LEVEL	TIME IN THE SHOWER	HOT WATER USAGE	COLD WATER USAGE
1	Crado S1002	---	slightly longer, same, slightly less	no difference	no difference
2	Waltec 76594	slightly noisy to very quiet	same to slightly longer	no difference	no difference
3	Con-serv Nova 86402	slightly noisy	same	no difference	no difference
4	Adamson 323 Turbojector	slightly to moderately noisy	same to slightly longer	no dif. to lower	no difference
5	Transcontinental Standard	---	same	no difference	no difference
6	Chicago Sp. 123WS	slightly noisy to very quiet	same to slightly longer	no difference	no difference
7	Jenkinson 6001C	slightly noisy to very quiet	same	no difference	no difference
8	Moen 3936	very quiet	same	no difference	no difference
9	Chicago Sp. 127C	slightly noisy	same	no difference	no difference
10	Chatham 44-3S	slightly noisy to very quiet	same	no difference	no difference

5 - Excellent
4 - Good
3 - Satisfactory - Excellent
2 - Fair
1 - Poor

TABLE 4.4 PREFERENCE GROUP CHARACTERISTIC RATING

CHARACTERISTICS	2 POINTS	3 POINTS	4 POINTS
Flow Rates (L/min)	#1 4.4 #2 4.6 #3 6.6 #4 7.0 #6 7.5	#5 7.1	#7 7.6 #8 8.8 #9 18.6 #10 11.7
Average Flow Rate for Group (L/min)	6.0	7.1	11.7
Average Spray Acceptance Rating	2	3	3.25
Average Water Pressure Acceptance Rating	2.4	3	3.75
Water Pressure	Light 43% Moderate 43% High 14%	Moderate 100%	Moderate 67% High 33%
Spray Width	Narrow 44% Medium 44% Wide 12%	Narrow 50% Medium 50%	Narrow 20% Medium 20% Wide 60%
Spray Size	Fine 67% Medium 33%	Medium 100%	Fine 25% Medium 75%
Spray Pattern	No centre 50% Uneven 50%	No centre 50% Heavy centre 50%	No centre 66% Heavy centre 17% Even 17%
Time in the Shower	Same 50% Slightly longer 40% Slightly less 10%	Same 100%	Same 100%

The highest group, "liked slightly to moderately", was perceived to have a medium to fine spray, a wide spray width and produced moderate pressure.

When flow rates of the showerheads in each group (obtained from the laboratory evaluation phase of the program) were averaged by preference group, the least liked group had an average flow rate of 6.0 litres/minute. The singular sample from the middle group had a flow rate of 7.1 litres/minute. The group of most liked samples had an average flow rate of 11.7 litres/minute.

Tables 4.5 to 4.7 summarize overall preference ratings and significant characteristics for each preference group. Blank columns indicate user inability to agree on a particular characteristic for a showerhead.

If two or more responses appear in a column, this signifies that users could draw statistically valid conclusions but could not agree on one particular attribute. This could easily happen given the different adjustability ranges of many of the showerheads and the difference in home water pressures and flows.

4.3 Discussion of Subjective Test Results

Before the in-house user trial started the user panel were asked to rate their own showerheads. They were asked to rate (from hard to light) what kind of water pressure they normally use and to estimate the normal amount of time they spent in a shower.

Estimates of time spent in the shower varied from "1 to 5 minutes" to over 20 minutes. The majority of the responses, however, were in the 5 to 10 minute range.

TABLE 4.5 OVERALL PREFERENCE RATINGS

NO.	BRAND/MODEL	RAW MEANS	ROUNDED MEANS	MODAL	ANALYSIS OF VARIANCE	OVERALL PREFERENCE RATING (9 PT SCALE)*	OVERALL PREFERENCE RATING (5 PT SCALE)**
1	Crado S1002	3.3	3	1	4	3	2
2	Waltec 76594	4.2	4	1-2-3 (2)	4	3	2
3	Con-serv Nova 86402	4.6	5	2-3 (2.5)	4	4	2
4	Adamson 323 Turbojector	3.4	3	1-2 (1.5)	4	3	2
5	Transcontinental Standard	5.4	5	5	6	5	3
6	Chicago Sp. 123WS	3.2	3	1	4	3	2
7	Jenkinson 6001C	5.3	5	7-8 (7.5)	6	6	4
8	Moen 3936	5.95	6	8	6	7	4
9	Chicago Sp. 127C	6.2	6	7	6	6	4
10	Chatham 44-3S	6.8	7	7	6	7	4

* 9 PT SCALE = 9 pt - like extremely; 8 pt - like very much; 7 pt - like moderately; 6 pt - like slightly; 5 pt - neither like nor dislike; 4 pt - dislike slightly; 3 pt - dislike moderately; 2 pt - dislike very much; 1 pt - dislike extremely

** 5 PT SCALE = 5 - Excellent; 4 - Good; 3 - Satisfactory; 2 - Fair; 1 - Poor

TABLE 4.6 SPRAY ACCEPTANCE RATINGS

NO.	BRAND/MODEL	RAW MEANS	ROUNDED MEANS	MODAL	ANALYSIS OF VARIANCE	SPRAY ACCEPTANCE RATING
1	Crado S1002	1.9	2	1	2	2
2	Waltec 76594	2.2	2	2	2	2
3	Con-serv Nova 86402	2.5	3	2	2	2
4	Adamson 323 Turbojector	1.8	2	1	2	2
5	Transcontinental Standard	3.3	3	3-4 (3.5)	3	3
6	Chicago Sp. 123WS	2.2	2	1	2	2
7	Jenkinson 6001C	2.95	3	4	3	3
8	Moen 3936	3.4	3	4	3	3
9	Chicago Sp. 127C	3.2	3	3-4 (3.5)	3	3
10	Chatham 44-3S	3.7	4	4	3	4

5 - Excellent; 4 - Good; 3 - Satisfactory; 2 - Fair; 1 - Poor

TABLE 4.7 WATER PRESSURE ACCEPTANCE RATINGS

NO.	BRAND/MODEL	RAW MEANS	ROUNDED MEANS	MODAL	ANALYSIS OF VARIANCE	WATER PRESSURE ACCEPTANCE RATING
1	Crado S1002	1.8	2	1	2	2
2	Waltec 76594	2.5	3	2	2	2
3	Con-serv Nova 86402	2.9	3	2	3	3
4	Adamson 323 Turbojector	2.6	3	1-4 (2.5)	3	3
5	Transcontinental Standard	3.4	3	3-4 (3.5)	3	3
6	Chicago Sp. 123WS	2.3	2	1	2	2
7	Jenkinson 6001C	3.6	4	5	3	4
8	Moen 3936	3.2	3	4	3	3
9	Chicago Sp. 127C	3.8	4	4	3	4
10	Chatham 44-3S	3.8	4	4	3	4

5 - Excellent; 4 - Good; 3 - Satisfactory; 2 - Fair; 1 - Poor

The water pressure most used by the panel for their own showerheads varied from moderate to heavy; no one used light pressure. Of the 19 people tested, 3 disliked their own showerheads, 2 neither liked nor disliked their showerheads and 14 liked their showerheads slightly to extremely well.

After the test was completed, users were asked to re-evaluate their own showerheads, yielding some interesting responses.

Of the 3 people who disliked their showerheads, 1 rated it higher than previously, 1 rated it the same and 1 rated it lower.

Of the 2 people who neither liked nor disliked their showerheads, 1 re-rated it higher and the other re-rated it lower.

Of the 14 people who liked their showerheads before the test, 7 rerated their own showerheads higher, the other 7 users' ratings remained unchanged.

There appear to be some inconsistencies in the results. The spray pattern assessment for the Transcontinental Standard and Chatham showerhead list both extremes as statistically significant responses. The Transcontinental Standard was not adjustable, and was perceived as having both a heavy centre with light perimeter and no centre spray. This might be attributed to varying water pressures in the users' households.

The Chatham was perceived by different users as having no centre spray, a heavy centre spray and an even spray pattern. This is possibly due to the fact that it has a large range of adjustability.

Inconsistencies also appear in the spray adjustability ratings. The Con-serv is adjustable, but was perceived by some users as being not adjustable. This may be because the Conservo's flow interrupt mechanism allows users to shut off the showerhead without touching the hot and cold taps.

It is possible that the users engaging this interrupt mechanism could not distinguish changes in the spray pattern and consequently perceived it as not having an adjustable spray pattern, only an adjustable water flow.

The Adamson Turbojector which also contains a flow interrupt mechanism also was rated in an inconsistent manner. It was perceived as being not adjustable and as having a poor spray pattern adjustability range. In this case, it is possible that some of the users could tell the difference in the spray pattern when this mechanism was used. Consequently, the users either interrupted the flow completely and said it wasn't adjustable or interrupted the flow only slightly and said it has a poor adjustability range.

The inconsistencies in the user's perception of spray adjustability for the Con-serv and Turbojector showerheads could be eliminated over time as users became accustomed to the showerhead's particular characteristics.

In all other categories of "difference testing", users identified each of the showerhead's characteristics with either one statistically significant response or a range for the characteristic, (i.e. the Crado had a fine spray size and a narrow to medium spray width). Since six of the showerheads are adjustable and considering potential differences in home plumbing systems, this was not unexpected.

Half of the tested showerheads are grouped into the lowest overall "dislike moderately to slightly" category. These are the Crado, Waltec, Con-serv, Adamson and Chicago Specialty 123 WS. Their spray acceptability ratings were consistently low (fair) because of their fine spray size, narrow to medium spray widths and moderate to light water pressure characteristics. It seems that users felt this combination of characteristics produced fair showers but with too little water and not enough water distribution.

The only showerhead rated as "neither liked nor disliked" was the Transcontinental showerhead; it tended to have average characteristics such as medium to fine spray width, medium spray size and produced a satisfactory shower under moderate pressure. In addition, the spray acceptability and water pressure acceptability ratings were satisfactory.

The four highest rated showerheads, the Jenkinson, Moen, Chicago Specialty 127C and Chatham were categorized "liked slightly to moderately". Their spray acceptance ratings ranged from satisfactory to good and their water pressure ratings were the highest.

The characteristics that led to high ratings were medium to fine spray size, wide spray width and, moderate to high water pressure.

Other evaluated characteristics were, in some instances, correlated to the overall preference rating. Statistical analysis of water spray patterns indicated that the showerheads were perceived as having no centre spray. The exception was the Adamson Turbojector which was considered uneven and lopsided. Similarly, the lowest rated group was perceived to have no centre spray and to be uneven or lopsided in spray pattern.

The Transcontinental Standard showerhead was rated as satisfactory. It was perceived as having a heavy centre spray pattern or no centre spray pattern as described earlier.

The highest rated group of showerheads had no centre spray and were not considered uneven. One, the Chatham showerhead, was adjustable and was rated by users as having both a heavy centre, no centre spray and as being even. The rating depended on the adjustment of the spray pattern that each user found optimal, as well as variations in water pressure.

The adjustability range of all adjustable showerheads could not be directly related to the overall preference rating. The lowest rated and highest rated preference groups contained both non-adjustable and adjustable showerheads.

Users thought that all adjustable showerheads had poor adjustability ranges, with the exception of the Chatham, for which adjustability ratings were split between good and poor.

Operational noise levels were not a factor in the preference ratings because all ranged from slightly noisy to very quiet. Users could not agree on a specific noise level for the Crado and the Adamson was rated slightly to moderately noisy. This could be related to the fact that the Adamson produced a sputtering spray action.

The amount of time the users took to shower suggested trends that can be related to overall preferences. For the lowest rated group of showerheads it was felt that more time was needed. Of the showerheads in this group, the Crado showerhead users indicated that they spent slightly less to slightly longer in the shower. For all the other showerheads in this group the users showered either the same amount of time or slightly longer. Generally speaking, with this lower rated group, the users felt that they had to stay in the shower slightly longer than with their own showerheads. They were not staying in the shower longer because they enjoyed it as represented by the low preference scores. One conclusion that could be drawn indicates that the users were staying in the shower longer because of the inadequacies of the showerheads.

No conclusions could be drawn from the hot and cold water usage data. The results seem to indicate that it was hard for most people to gauge hot and cold water use.

Some testers reported that the Adamson Turbojector showerhead used different mixtures of hot and cold water than the others but most noticed no difference. Those that did, however, felt they used less hot water than normal.

Overall, the test highlighted trends and specific characteristics liked and disliked on all showerheads.

A subcontract was awarded to Hooper and Angus Associates Limited to use the results of the testing, in combination with best available data relating to hot water use in other building categories, as a basis for making estimates of typical savings in utility costs and water commodity charges resulting from use of low-flow showerheads in the following categories of building:

- Single Family Residence
- Family Apartment
- Adult Apartment
- Senior Citizen's Apartment
- Hotel
- Recreational Facility
- School

Due to problems in the field test portion of the program (discussed earlier in this report), a significant input into the study of cost savings potential was not available (i.e. hot and cold water consumption under actual conditions). This phase of the program, therefore, relies heavily on the laboratory test results, as well as hot water reduction estimates from other studies.

5.1 Test Methods

The following analytical procedure was developed:

- Initially it was intended that test results of showerheads in laboratory and under actual use conditions would be employed to provide estimates of hot water savings from low-flow showerheads. Due to the lack of field test data comparing actual hot and cold water consumption between conventional and low-flow type showerheads, estimated water savings were based primarily on laboratory results.

- Hot water use patterns for different building categories (with specific information on shower use characteristics) were established, in order to supply information on the base amount of hot and cold water used by showering. This data would also indicate the areas of greatest potential for energy savings.

- Combining the above with assumed DHW system efficiencies and fuel costs for the various building categories produced estimates of potential cost savings due to low-flow showerheads. These cost savings result from reduced energy consumption associated with hot water usage reduction as well as reductions in commodity charges brought about by reduced overall water consumption.

Cost savings from low-flow showerheads was estimated for the seven building categories listed earlier.

Most of the information obtained during the study on DHW use profiles and shower use characteristics relates to the residential building sector, including single and multiple family dwelling units.

Information on hot water use in hotels and schools was more difficult to obtain and required certain approximations as described in the following sections.

Hot water use characteristics for recreational facilities proved very difficult to obtain and assumptions were necessary. These are also detailed in the following sections.

5.2 Findings

5.2.1 Flow Reduction-Review of Information

The flowrate of both conventional and low-flow showerheads, in actual use, is not well documented.

The manufacturers of low-flow showerheads commonly claim that the flowrate through their showerheads is 8-12 L/min. This claim is supported through several independent studies [2,4,5,6]. These manufacturers also claim that conventional showerheads have flowrates of 20-30 L/min. These figures would indicate a reduction in flow of between 40 and 73%. Some evidence exists that flowrates of conventional showerheads in actual use are lower than indicated and are normally around 15 L/min [2,4], thus reducing the claimed savings to the 20-47% range.

Table 5.1 presents some test results for both conventional and low-flow showerhead types.

Flowrates for conventional showerheads shown in the table average about 15 L/min. Values for low-flow showerheads can be seen to vary over a broad range of flowrates.

Two studies which investigated both conventional and low-flow showerheads [2,4], noted an increase

TABLE 5.1 SHOWERHEAD FLOWRATES QUOTED

Showerhead Type	Flowrate (L/min) [ref]
Conventional	11.6 [4]
Conventional	18.3 [7]
Conventional	12.9 [2]
Average Conventional	14.3
Low-Flow	8.1 [4]
Low-Flow	7.2 [2]
Low-Flow	8-12 [5]
Low-Flow	- [8]
Low-Flow	- [9]
Low-Flow	4.4-13.3 [6]
Average Low Flow	8.6

in either the mixed water temperature or the showering time. Either of these situations leads to an increase in hot water requirements over the amount predicted from simple flowrate reduction estimates.

In one of the better documented shower use studies, conducted at Kansas State University [4], careful attention was given to both the amount and temperature of water used for showering with both conventional and low-flow showerheads. The results indicated that a conventional shower used 36 L of water at 38.9°C while a shower taken with a low-flow showerhead used 24 L at 41.1°C. Thus, while the low-flow unit provided a 33% reduction in water consumption, this only represented a 28% saving in energy.

Another study [2], which assumed no difference in the mixed water temperature, noted a 6% increase in shower time when low-flow showerheads were used. Combined with a 44% reduction in mixed water flowrate, this results in an overall hot water consumption saving of 40%.

From these figures one can calculate that a reduction in hot water savings estimates obtained from flowrate comparisons of approximately 5% can be expected due to an increase in either shower temperature or shower time. For this reason, and using a 40% reduction in mixed water flowrate, one can predict that low-flow showerheads would result in an average 30% saving in energy consumption for shower purposes, and a 33% reduction in water consumption.

These numbers are approximations and will not be accurate for all low-flow showerheads under all use conditions.

The calculated 30% reduction in energy requirement and 33% reduction in shower mixed-water consumption are used in this study to develop estimates of the general cost saving potential from low-flow showerheads for all of the building categories covered.

5.2.2 DHW Use Profiles for Different Building Categories

While a reasonable amount of information is known about hot water use in general, there is little available data on hot water use by specific end application, such as showers. Only two references [3,7] were found which directly addressed these issues. One study [3] developed total weekly, per capita and per occurrence water usage characteristics for showers as a function of the total household hot water consumption. The same study analyzed the difference in total hot water consumption and shower usage for different family sizes, age groups, etc.

Using data from these sources, it was possible to develop estimates of average weekly hot water demand for each of the seven building categories as well as estimates of the percentage of hot water used by showers. These estimates are summarized in Table 5.2.

Values for hot water demand shown in Table 5.2 assume hot water at 60°C. For showers, a mixed water temperature of 40°C was assumed.

TABLE 5.2 AVERAGE WEEKLY HOT WATER DEMAND [3,7]

Building Category	Demand	Shower Demand (%)
Single Family Residence	1152 L	41
Family Apartment	1029 L/apt.	40
Adult Apartment	736 L/apt.	34
Senior Citizen's Apartment	412 L/apt.	30
Hotel	400 L/room	40
Recreational Facility	175 L/member	60
School (Public)	32 L/student	60
(Dormitory)	340 L/student	60

A CEA survey of 621 single family homes across Canada [3] revealed that an average household's weekly hot water consumption was 1152 L. Of this total, 469 L (or approximately 41%) was found to be used for showers. This was found to be the largest single use of hot water. Baths accounted for only 190 L (16%) of the average weekly hot water demand.

A number of surveys of apartment buildings included in an NRC report [7] indicated average weekly hot water demand for family apartments to be 1029 L/unit. As expected, this value is very close to that for single family dwellings. It is only slightly less than the total hot water consumption reported above, perhaps because of the small number of people in typical apartment units and reduced proportion of apartments with washing machines and dishwashers, compared with single family dwellings.

Adult apartment building hot water demand was based on the total weekly demand for households consisting of only one or two adults. The hot water demand in these instances was 678 and 794 L/week respectively. Assuming an even split of apartments containing one and two persons, an average weekly hot water demand of 736 L/apt unit was calculated.

A survey of senior citizen's apartment buildings [7] indicated an average weekly hot water demand of 412 L/apt unit.

Average weekly hot water demand for hotels, including requirements for kitchens, pool facilities and laundries, was found to be 400 L/room [7].

For apartments and hotels, the percentage of total hot water used for showers was estimated from an analysis of the hot water use profiles for family sizes ranging from 1 to 6 members and for age groups ranging from under 25 years to senior citizens.

For recreational facilities the percentage of hot water used in showers was found to range from 42 to 81% depending on whether the facility was considered to be a health club or spa, with dining and other features, or simply a gymnasium type facility.

A wide range of hot water demands were found for schools. Public school hot water demand ranged from 16 to 48 L/student, while for dormitory type buildings the average was found to be 340 L/student. For the purpose of this study only dormitory type applications are considered.

These estimates of weekly hot water consumption, and the proportion of the total attributable to showers for the different building types have been obtained from the best available information at the time of this report. There is no direct verification of the accuracy of these estimates, however.

5.2.3 DHW System Efficiencies and Fuel Costs

A literature review indicates that the main fuel used for domestic water heating in Canada is electricity, accounting for over 50% of the market, followed by natural gas with 35% of water heating market [10]. The remainder of the water heating market is divided between oil, propane, solar and other small contributors and is not covered by this analysis.

Table 5.3 lists the combined efficiencies for gas and electric residential domestic water heaters. For energy and cost saving calculations, seasonal efficiencies of 75 and 50 percent were assumed for electric and gas heaters, respectively.

TABLE 5.3 RESIDENTIAL DHW SYSTEM EFFICIENCIES [7]

Component	Water Heater Efficiency (%)	
	Electric	Gas
Conversion	100	70
Standby Loss	15	20
Distribution Loss	5-10	5-10
Combined Efficiency	75-80	50-55

Larger users of hot water, such as hotels and recreational facilities have lower standby losses. It was assumed that the DHW system seasonal efficiencies for these building categories are 85% and 65% respectively for electricity and gas.

Fuel costs were established for the various building categories located in Toronto. Fluctuations in fuel cost with location or time will affect the energy cost savings and can be estimated accordingly.

Table 5.4 shows that fuel costs for natural gas and electricity are $5.97/GJ and $0.05/kWh for single family dwellings. Fuel costs average at $4.83/GJ and $0.025/kWh for larger users such as hotels and schools.

TABLE 5.4 FUEL COSTS

Building Category	Electric ($/kWh)	Gas ($/GJ)
Residential	0.050	5.97
Commercial	0.025	4.83

5.2.4 Energy Cost Savings Potential

Based on the weekly demand estimates shown in Table 5.2 and the assumption given earlier of a 30% reduction in hot water consumption for low-flow showerheads, hot water savings for each building type can be summarized as in Table 5.5.

TABLE 5.5 AVERAGE WEEKLY HOT WATER SAVINGS

Building Category	Weekly Savings
Single Family Residence	141.7 L
Family Apartment	123.5 L/apt.
Adult Apartment	75.1 L/apt.
Senior Citizen's Apartment	37.1 L/apt.
Hotel	48.0 L/room
Recreational Facility	31.5 L/member
School (Dormitory)	61.2 L/student

Taking mains water temperature of 10°C, and using the system efficiencies described earlier, energy cost savings can be calculated. These are summarized in Tables 5.6 and 5.7.

TABLE 5.6 ENERGY COST SAVING POTENTIAL - ELECTRIC

Building Category	Weekly Savings (kWh)	Annual Savings ($)
Single Family Residence	11.0	28.50
Family Apartment	8.4	11.00/apt.
Adult Apartment	5.1	6.70/apt.
Senior Citizen's Apartment	2.5	3.30/apt.
Hotel	3.3	4.30/room
Recreational Facility	2.1	2.80/member
School (Dormitory)	4.2	5.40/student

TABLE 5.7 ENERGY COST SAVING POTENTIAL - GAS

Building Category	Weekly Savings (MJ)	Annual Savings ($)
Single Family Residence	59.3	18.40
Family Apartment	39.8	10.00/apt.
Adult Apartment	24.2	6.10/apt.
Senior Citizen's Apartment	11.9	3.00/apt.
Hotel	15.5	3.90/room
Recreational Facility	10.1	2.50/member
School (Dormitory)	19.7	4.90/student

5.2.5 Cost Savings Potential of Reduced Water Consumption

The potential savings in commodity charges for the various building types can be calculated as follows. Hot water for showering (conventional showerhead) can be read off from Table 5.2. Making the same water temperature assumption as used for the energy cost savings calculations, one can calculate the total amount of water used for showering purposes. The reduction in water consumption from low-flow showerheads can then be computed, based on commodity charges which apply to the water. Tables 5.8 through 5.10 provide the figures for the various building sectors based on prevailing water rates for the city of Toronto. Water rates are $0.454/1000L plus 15% surcharge for sewage service, or $0.522/1000L total charge for residential, commercial and industrial service (October, 1985).

5.2.6 Combined Cost Saving Potential

The combined effect of lower total water usage charges and reduced costs to heat the hot water portion are shown in Table 5.11. From this table, it can be seen that low-flow showerheads appear particularly attractive and offer good payback for single family residences and family apartments. Adult apartments and senior citizens apartments do not appear as attractive for low-flow showerheads.

TABLE 5.8 AVERAGE WEEKLY SHOWER DEMAND (Conventional Showerhead, based on 60°C hot water, 10°C cold water, 40°C mixed water temperatures)

Building Category (L)	Hot Water (L)	Cold Water (L)	Total Water
Single Family Residence	472	315	787
Family Apartment	412	274	686/apt.
Adult Apartment	250	167	417/apt.
Senior Citizen's Apartment	124	82	206/apt.
Hotel	160	107	267/room
Recreational Facility	105	70	175/member
School (Dormitory)	204	136	340/student

TABLE 5.9 AVERAGE WEEKLY WATER SAVINGS (Based on 33% water savings over conventional showerheads.

Building Category	Weekly Savings
Single Family Residence	260 L
Family Apartment	226 L/apt.
Adult Apartment	138 L/apt.
Senior Citizen's Apartment	68 L/apt.
Hotel	88 L/room
Recreational Facility	58 L/member
School (Dormitory)	112 L/student

TABLE 5.10 COMMODITY SAVING POTENTIAL - WATER (Based on $0.522/1000 L water, City of Toronto)

Building Category	Annual Savings (L)	Annual Savings ($)
Single Family Residence	13520	7.05
Family Apartment	11752	6.15/apt.
Adult apartment	7176	3.75/apt.
Senior Citizen's Apartment	3536	1.85/apt.
Hotel	4576	2.40/room
Recreational Facility	3016	1.55/member
School (Dormitory)	5824	3.05/student

It should be pointed out that for most single family residences and apartments (if only one shower is present) the savings represent savings per installation and thus, simple payback can be calculated. However, for schools and recreational facilities, savings are presented on a per user basis. Even though these values appear low, the higher number of users per showerhead would greatly enhance the savings potential in these areas. If, for example, a recreational facility had one shower for every 100 members, the annual savings per showerhead would be in the range of $405 to $435, making low-flow showerheads an extremely attractive investment.

TABLE 5.11 PRELIMINARY ESTIMATE OF COMBINED COST SAVINGS - LOW-FLOW SHOWERHEADS

Building Category	Annual Energy Savings		Annual Water Use Savings	Combined Savings
	Gas DHW	Electric DHW		
Single Family Residence	$18.40	$28.50	$7.05	$25.45 to $35.55
Family Apartment (Per Apt.)	$10.00	$11.00	$6.15	$16.15 to $17.15
Adult Apartment (Per Apt.)	$ 6.10	$ 6.70	$3.75	$ 9.85 to $10.45
Senior Citizen's Apartment (Per Apt.)	$ 3.00	$ 3.30	$1.85	$ 4.85 to $ 5.15
Hotel (Per Room)	$ 3.90	$ 4.30	$2.40	$ 6.30 to $ 6.70
Recreational Facility (Per Member)	$ 2.50	$ 2.80	$1.55	$ 4.05 to $ 4.35
School (dormitory) (Per Student)	$ 4.90	$ 5.40	$3.05	$ 7.95 to $ 8.45

NOTE:

(1) Above estimates are based on 33% reduction in flowrate with low-flow showerhead but only 30% reduction in energy use because of increased shower time and/or increased fraction of hot water use.

(2) Cost savings for reduced water consumption are based on City of Toronto water rates as of Oct. 1985 and include 15% sewage surcharge.

The results of the project indicate that there is a significant cost saving potential from low-flow showerheads. The subjective evaluation study undertaken during the project showed that the performance of half of the test showerheads was rated neutrally or better (combining the categories "neither liked nor disliked" and "liked slightly to moderately" accounts for half of the showerheads).

From this one can conclude that low-flow showerheads are available with flow characteristics which are acceptable to many users. Usage of low-flow showerheads will result in significant cost savings for certain building categories, according to the preliminary cost savings estimate developed in the report.

The most attractive installations for low-flow showerheads are these with a high number of users per showerhead such as recreational facilities and schools. Single family residences and, to a lesser degree, family apartments are also good candidates for application of low-flow showerheads. By contrast, cost savings from low-flow showerheads probably do not warrant the investment for adult apartments, senior citizens' apartments or hotels.

The study demonstrated that battery operated shower monitors can be used to measure the duration and frequency of showers use. Start-up problems, heating system changes and unexpected vandalism problems make the validity of data obtained from the shower monitors questionable for the existing program.

It is recommended that a further study be carried out to validate the preliminary cost savings estimates developed in this report. We would make the following suggestions concerning a follow-up study:

- Showerheads should be selected covering a broader range of flowrates in tests similar to the laboratory evaluation phase of this study for further field trials. The showerheads tested at Columbus Centre included only one "conventional head". Testing of a broader sample might provide data relating to user acceptance as well as energy savings of low-flow showerheads, vis-a-vis "conventional" units, rather than simply monitoring energy and water use of a sample of low-flow showerheads.

- Efforts should be made to obtain prompt feedback from the shower users about any strong likes or dislikes for a particular showerhead. This may avoid the situation which occurred at Columbus Centre, where the monitoring equipment and showerheads were twice damaged.

- Great care should be taken in selection of a test site in an attempt to find willing participants. In the present program, the members of the health club were, in general, interested in the work being undertaken, but there were a few individuals who used the study to vent their frustration with the management of the centre. Preliminary discussions have been held with a utility company who have expressed an interest in participating in such a field study.

1. CSA Preliminary Standard F379-M1982 "Solar Domestic Hot Water System: Liquid to Liquid Heat Transfer", CSA, Rexdale, Ont.

2. Interim Report: "Residential Water Conservation Projects", Brown & Caldwell Consulting Engineers, for Building Technology Division, Office of Policy Development & Research, U.S. Dept. of Housing & Urban Development, Washington, D.C. 20410, Feb. 83, 52 pp.

3. "Residential Hot Water Use Patterns" Canadian Electrical Association Report Number 111 U 268, Vol. II, July 1983.

4. "Showering Behaviour: Implications for Water and Energy Conservation". Rolles, F.H. Jr. and Kone, S.A.. Ashrae Transactions, Part 1, 1982.

5. "Technical Evaluation of Water/Energy Saving Showerheads for Naval Supply Center, Oakland" Suier, J.L. and Smith, C.R., Civil Engineering Laboratory, Naval Construction Battalion Centre, Port Hueneme, Ca. 93043 December, 1975.

6. "Testing of Domestic Hot Water Use Reduction Devices" Ontario Research Foundation, BETT Report No. OR.83-03, March, 1984, unpublished.

7. "Energy Requirements for Domestic and Service Hot Water" Division of Building Research, National Research Council of Canada, January, 1981.

8. "State-of-the-Art Review of Domestic Hot Water Production and Use in the Residential Sector" Ontario Research Foundation. BETT Report No. OR.82-32B, September, 1983, unpublished.

9. "Factors Affecting the Energy Consumption of Showerheads" Ontario Hydro Research Division, Toronto, Ontario. Report No. 79-274-K, August, 1979.

10. "Household Facilities and Equipment" Statistics Canada, Catalogue No. 64-202, May, 1979.

APPENDIX A

A.1 Survey Questionnaire

Attention: Marketing Manager

Dear Sir,

We are preparing a data base of devices for reduction of energy use in domestic hot water production. To ensure that your products are included in this data base, please send product literature and a list of (Canadian) distributors for the following products which your company manufacturers or distributes, particularly those designed to conserve hot water:

Aerators
Faucets
Flow restricting inserts or fittings
Instantaneous hot water heaters
Showerheads
Showerhead adaptors

We would also ask for any written material which you could make available regarding testing of the actual energy reduction resulting from the above devices.

Please do not hesitate to contact us should you have any questions regarding this request. A mailing label is enclosed for your convenience. Your assistance with this request will be greatly appreciated.

Sincerely,

Dept. of Engineering and Metallurgy

Encl.

Table A.1 Commercially Available Conservation Devices

Company	Number of Models Available		
	Low-flow Faucet Aerators	Low-Flow Showerheads	Low-Flow Showerheads Inserts
Aristocrat Mfg. Co. Ltd. 4500 Dixie Road Mississauga, Ont. L4W 1V7	-	-	1
Cambridge Brass (Div. of Waltec) 140 Orion Place Cambridge, Ont. N1R 5V1	1	2	-
Chicago Specialty Mfg. of Canada Ltd. (Sister Co. of Wrightway) 70 Morton St. E. Brantford, Ont. N3T 5T6	1	1	-
Jenkinson and Company 23 Chaucey Ave. Toronto, Ont. M8Z 2Z2	1	9	1
N.K. Douglas Enterprises Box 125 Ilderton, Ont. NOM 2AO	1	1	-
Plumbmaster Div. of NCH Canada Ltd. P.O. Box 15 Mississauga, Ont. L4T 3B5	1	2	3
Tradeway Sales 270 Evans Avenue Toronto, Ont. M8Z 1J8	2	3	4
Transcontinental Energy Saving Products, Canada Ltd. Burlington, Ont.	-	4	-
Waltec Industries Wallaceburg, Ont. N8A 4L9	-	1	-
Wrightway Mfg. Co. 1050 Central Ave. Park Forest South, Illinois, Mich. 60466	3	6	2

A.2 Letter From Columbus Centre

ITALIAN CANADIAN
BENEVOLENT
CORPORATION

901 Lawrence Ave. W.
Toronto, Ontario
M6A 1C3
(416) 789-7011

Community Projects:
VILLA COLOMBO
COLUMBUS CENTRE
CABOTO TERRACE

August 14, 1984

Mr. Lou Bruno, P. Eng.
Ontario Research Foundation,
Sheridan Park Research Community,
Mississauga, Ont.
L5K 1B3

Dear Mr. Bruno:

I would like to start off by thanking you for the informative meeting that took place on August 9th at Columbus Centre.

As I expressed to you, I was indeed interested in having your company install monitoring devices to study different types of shower heads and monitor consumption of water used.

It is my understanding that the following conditions would apply:

1) Columbus Centre would allow your company access to the men's Health Club.

2) Ontario Research would take out a membership.

3) Ontario Research would be totally responsible for all costs incurred for the installation of any equipment necessary for the testing.

4) You would also be financially responsible for any repairs or renovations necessary after testings are completed.

In short, Columbus Centre is not and will not be responsible for any expenditures of any kind relating to the proposed testing. If these terms are correct and acceptable to your firm, I invite you to start testing as soon as possible.

Yours truly,

L. Circosta

Loretto Circosta,
Property Manager

LC/am

Donations, gifts and bequests make it possible for the ICBC to provide services to the Community
Italian Canadian Benevolent Corporation, a charitable organization chartered under the laws of the Province of Ontario Reg. No. 0384305-01 13

A.3 Sampling of Questionnaires

A sample of the questionnaire used by the members of the Columbus Centre is shown on the following page. Below are some of the comments noted by members:

"The nozzle in use today was fine. Not too little, not too much water. The nozzle that looks like the air intake for a jet engine is terrible! Not enough water, too much mist!!"

"No good! Stop fooling around! Membership at stake!"

"Why do we have to waste time and money on this kind of thing? You have fooled around with 3 to 5 kinds of showerheads. The feedback for the most part has been negative. You don't seem to heed it."

"Please remove the showerheads. They do not function properly."

"Get these things out!!! I don't like intervenus (sic) showers!"

"The showers are so poor, water only trickles, and cold, that I am not going to renew my membership. For $400.00 fee I expect this only luxury."

"Seems okay."

"These showerheads are the pits! We haven't had a decent showerhead for two years!"

"Underwater shock treatment when other shower goes on - hot becomes cold!"

"This research serves absolutely no purpose for humans. Don't waste my and other taxpayers' money! Leave the damn water alone!"

"Temperature is fine, pressure is weak."

ONTARIO**RESEARCH**
FOUNDATION

QUESTIONNAIRE
OPINIONS ON SHOWER

MODEL: CHATHAM 44-3S

The ONTARIO RESEAERCH FOUNDATION would appreciate any comments you may have regarding the showerhead installed on these premises.

By circling a number from 1 to 5 (with 5 being the highest rating) we could get an idea of how you felt about the shower.

	POOR ——— GOOD				
How would you rate the shower spray	(1)	2	3	4	5
How would you rate the length of time this shower took compared to other showers taken (long 1---short 5)	(1)	2	3	4	5
How would you rate the hot water temperature compared to other showers taken	(1)	2	3	4	5
How would you rate this shower with your home shower	1	2	3	4	(5)

COMMENTS: GET THESE THINGS OUT!!!

I DONT LIKE INTERVENUS SHOWERS